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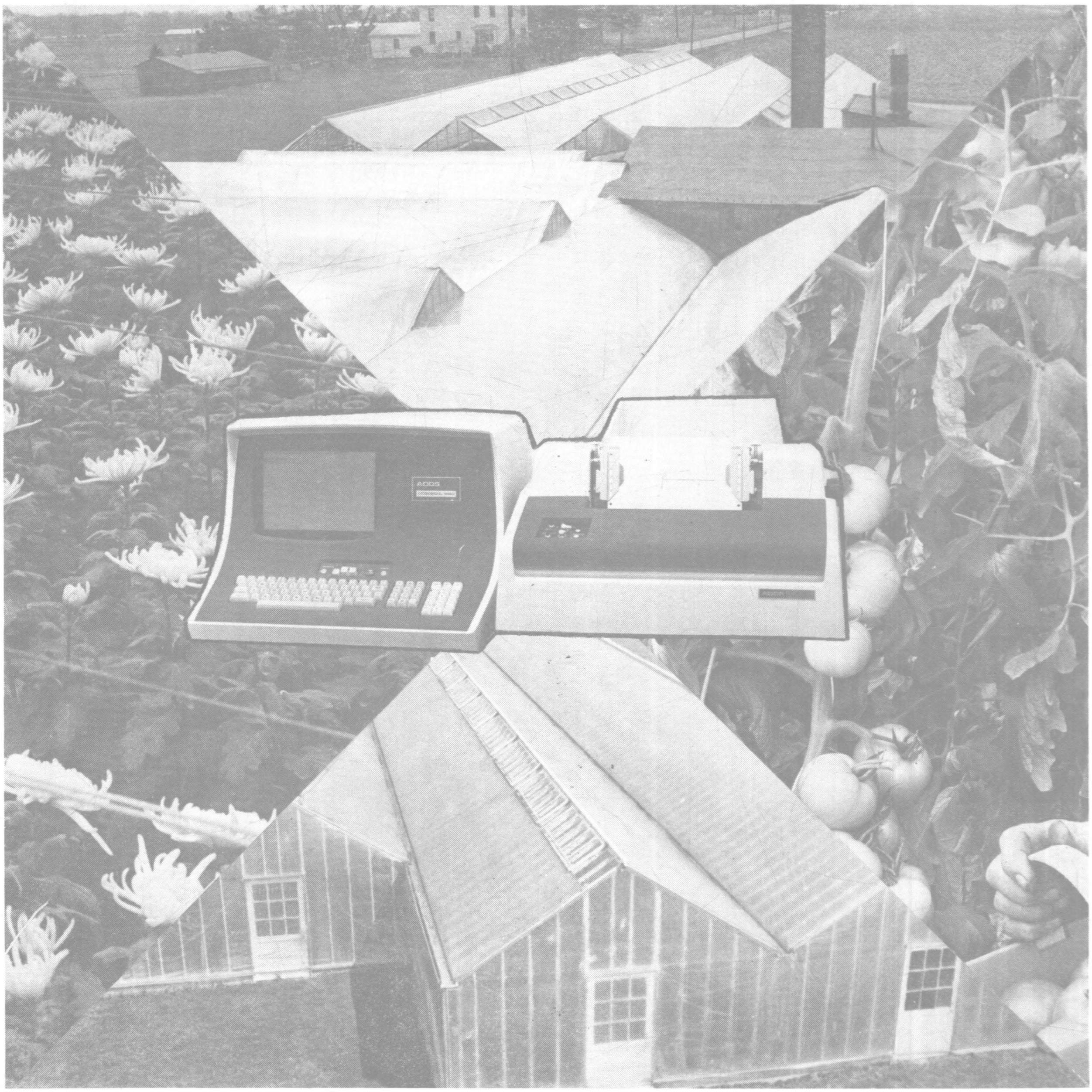

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FOREWORD

This publication is an initial step in promoting greater economic analysis of greenhouse energy conservation investments by growers. It contains detailed discussions of greenhouse energy conservation investment evaluation criteria, methodologies for evaluating greenhouse energy conservation investments, and specific applications of discounted cash flow to evaluations of double-layer, air-inflated polyethylene over glass, internal curtains, and glass lap sealants.

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DAVID B. PERRY and JERRY L. ROBERTSON[1]

INTRODUCTION

Energy conservation, the development of energy-saving technologies, and the development of alternate energy sources have received considerable attention. While on-going research into energy conservation is very critical, it is equally important to evaluate the economics of conservation measures. Energy conservation in a commercial production environment serves little purpose for growers/businessmen if the conservation measures are not economically justifiable. If there is to be widespread adoption of energy conservation measures or alternate energy sources, research must be directed with the objective of developing economical conservation measures.

Prior to the 1970's, the cost of energy for production of greenhouse crops accounted for only 5-10% of production expense. Inexpensive fuel enabled many growers to produce crops at what might now be considered extravagant temperatures and in a manner that often amounted to inefficient use of greenhouse space. Many of these operations are now less profitable because of the growers' inability to cope with an inflationary economy, stable prices for finished products, and rapidly rising production costs. Energy is now the second largest single expense in the operation of a commercial greenhouse, accounting for approximately 20% of production costs. Growers have little control over an inflationary economy, the minimum cost of labor, or stable market product prices, but energy costs can be controlled and reduced significantly.

All growers have available practical energy-saving practices. These include: 1) optimum maintenance of heating equipment, 2) proper location of temperature controls, 3) high boiler operating efficiency, 4) greater use of insulation, 5) use of high quality water in heating systems, and 6) production of crops which can be produced at lower temperatures.

In addition to these energy-saving practices, several other methods are in various stages of development. The major energy conservation techniques are:

- Double-layer, air-inflated polyethylene over glass
- Internal curtains
- Glass lap sealants

These techniques offer varied advantages and disadvantages from both an economic and a cultural viewpoint. Adoption of one or more of these conservation methods can dramatically reduce energy costs.

This paper presents and discusses investment evaluation criteria for three major energy conservation technologies currently available. Two methodologies, Payback and Discounted Cash Flow, are explained and discussed. Discounted Cash Flow is developed to include the concepts of discounting, time value of money, present value, net present value, internal rate of return, and profitability index. Discounted Cash Flow is used to analyze an investment in double-layer, air-inflated polyethylene over glass, internal curtains, and glass lap sealants. A glossary is included at the end of the paper.

ENERGY CONSERVATION INVESTMENT EVALUATION CRITERIA

Basing a decision to invest in energy conservation equipment primarily on the initial investment cost fails to consider many factors that are important to an overall evaluation of any given investment. Both financial and nonfinancial considerations have an influence on the investment decision. Several criteria that should influence the investment decision are presented.

Financial Condition of the Business

Before an in-depth analysis of an energy conservation investment is undertaken, the relative financial condition of the business should be considered. Since all three major conservation investments have the same relative degree of risk, the financial condition of the business becomes the key factor as to whether an energy investment can be made.

Analyses of sales, profitability, fixed assets, liquidity, and leverage are all pertinent to any investment decision. Saving money on energy may prove to be of little value if the business is placed in a highly leveraged or low liquidity position because of an energy conservation investment. Determination of the amount of capital that is or could feasibly be available for an energy investment should be helpful in determining which investments should be seriously considered.

Energy Efficiency

A major factor influencing the decision to invest in an energy-saving technology is the energy efficiency of the current facility. If fuel accounts for

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25% of total production cost, a 50% fuel savings with all other factors constant results in a relative energy cost of 12.5% of total original production cost. Therefore, a structure with a 25% relative fuel cost may justify a specific energy-saving technology that could not be justified in a structure with only a 5% fuel cost.

Growers who have not reinvested in greenhouse improvements and have less heat-efficient structures will witness the greatest fuel cost escalation as the prices of oil and natural gas increase. Growers whose greenhouses are heat-efficient or are located in a lower energy-use area may have less need to invest.

Initial and Future Expenditures

The magnitude of initial and future capital outlays required for a given technology is important in the analysis of the potential investment. Different investments create differences in the timing of returns. For example, double-layer poly used on existing greenhouses requires only minor structural changes and a comparatively low initial investment, resulting in a relatively shorter pay-off period. In contrast, a solar-heated greenhouse requiring extensive new equipment and a comparatively high initial investment will have a relatively longer pay-off period. Usually, the productive or economic life of the energy-saving asset determines the time period used for planning.

Energy conservation investments frequently require significant material replacement costs in the future. For example, the costs of polyethylene replacement with double-poly over glass or fabric replacement with internal curtains are costs to be considered in the overall planning horizon for evaluating energy conservation investments.

Because of the variable nature of initial and future capital outlays, time is a critical factor in the evaluation of energy conservation investments. Long-term planning is essential for analyzing a technology on the basis of its cost and effect on returns because current decisions are influenced by past decisions. Greenhouse energy conservation investments should be planned over a sufficient time period so as to weigh the investment decision carefully, considering all relevant economic factors. Analyzing the initial expenditure, operating costs, returns, and the potential effect on yield over the life of the investment results in a comprehensive look at an investment's net contribution to the business.

Return on Investment

The individual grower should make the investment decision considering rate of return on investment. Maximization of profit is the objective of a business, but profit is an incomplete measure of a business' performance because it does not consider the amount of invested capital. Rate of return on investment is a common denominator which allows comparison of investments, individual businesses, and industries.

A grower with a current return on investment of 20% is likely to want at least a 20% return on any investment in energy conservation measures. If the 20% return on investment cannot be obtained, the grower might be better off expanding production facilities rather than investing in a technology with a lower rate of return. If the greenhouse grower is currently receiving a 5% return on investment, an energy-saving technology returning 20% would be a justifiable investment.

Energy Conservation vs. Yield

Consideration should first be given to what constitutes an energy-saving, cost-reducing technology. The obvious parameters include any device or practice that reduces the cost of energy for a given crop or the same amount of production and degree of quality at a reduced cost, which results in a lower energy cost per unit produced.

Another way to consider an energy-saving, cost-reducing technology is in the sense of increasing production yield per unit of production area. Increased production/ft^2 also results in a lower energy cost per unit and is as cost effective as producing the same crop at a reduced outright energy expense.

Most energy-reducing technologies are cost-saving rather than yield-increasing. In some cases, yield may be reduced because of changes in the growth environment. Kirschling and Jensen found that a 1% change in yield for 4-inch potted chrysanthemums changed profit by 25%, but a 1% change in fuel use had a 2.2% influence on profit (6). Due to possible yield effects of an energy-saving technology on specific crops, a cost-saving tactic may eliminate any chance of paying off the cost of the technology due to reduced yield. Considerable caution should be exercised before choosing an investment that results in energy saving at the expense of product quality or lower productivity per unit area.

Technological Obsolescence vs. Higher Energy Costs

Growers should analyze the trade-off between making an investment in energy conservation measures today and continuing to pay higher energy costs. An investment today will reduce fuel costs, but the conservation method may be obsolete in a relatively short time. Growers may want to temporarily postpone investment in an energy-saving technology because technological development has and will continue to occur.

Flexibility and risk aversion are two basic principles of finance which become particularly important when considering the possibility of technological obsolescence. If two investments are comparable in many aspects, except their relative economic lives, the shorter-lived asset will probably be favored. Earlier availability of invested capital allows reinvestment after a new appraisal of energy-saving technologies and the general economic environment. In the short run, this means compensating for higher energy costs with productivity gains, while waiting for newer technologies to develop.

This decision rests with individual greenhouse owners, as each grower has a different financial planning horizon, in addition to differences in the perception and method of dealing with risk. The relative state of the art of energy conservation for greenhouses varies considerably from technology to technology, so a high capital commitment may not be warranted at this time. Evaluating the speed of development of new technology is important because new technological developments may make current decisions economically irrational.

Cultural and Product Quality Factors

Nonfinancial considerations are involved in evaluating energy conservation investments. Depending on the crop(s) being produced, certain conservation measures may be more or less appropriate. For example, double-poly over glass reduces light transmission, which might cause double-poly to be ruled out as a potential conservation technique in cases where high light intensity crops are being produced (4). Double-poly or lap sealants may change the greenhouse atmosphere by altering humidity and/or CO_2 levels (3). Changes in the greenhouse environment may necessitate cultural changes. Crop shading may be a factor with internal curtains when they are drawn back during the day.

Potential cultural factors with a given energy conservation investment should be analyzed by considering the trade-off between potential fuel savings and reduced productivity and/or loss in quality. Fuel savings may or may not justify a loss in productivity and/or quality.

Table 1 presents a summary of factors that should be considered in the evaluation of energy conservation investments.

TABLE 1.—Summary of Energy Conservation Investment Evaluation Criteria.

Financial Condition of the Business
Energy Efficiency
Initial and Future Expenditures
Return on Investment
Energy Conservation vs. Yield
Technological Obsolescence vs. Higher Energy Cost
Cultural and Product Quality Factors

METHODOLOGY FOR EVALUATING ENERGY CONSERVATION INVESTMENTS

A complete evaluation of any investment should include an analysis of the initial investment and all projected cash flows from the investment. A problem with examining investments that entail both costs and benefits over an extended period is placing a value on costs and benefits realized several years in the future. Due to a number of factors, the future cash flows must be reduced in value to reflect their worth today. Two approaches to analyzing this problem will be discussed.

Payback

One approach to the problem of placing a value on the cash flows from an investment would be to determine the investment's payback period. Payback is the time period for the future cash flows from an investment to equal the initial expenditure. For example, if an investment of $1,000 today yields savings totaling $1,000 within 1 year, the investment has a 1-year payback period.

The problem with payback is that it doesn't show recognition of the time value of money. The concept of money having a time value shows awareness of inflation, opportunity cost, and the increasing risk associated with realizing cash flows in the future. The timing of the cash flows from an investment is critical to the investment decision. For example, an investor should place a higher value on a given set of cash receipts over the next 5 years than on the same set of cash receipts 10 through 14 years from today. As cash flows extend farther into the future, they have less relative value today.

In Table 2, investment A would be of greater

TABLE 2.—Example of Payback Period for Two Investments.

Investment Outlay Net Cash Flow: Year	Investment A $ (10,000)	Investment B $ (10,000)
1	$ 5,000	$ 500
2	1,000	500
3	500	500
4	500	500
5	500	500
6	500	500
7	500	500
8	500	500
9	500	1,000
10	500	5,000
	$ 10,000	$ 10,000

Payback = 10 years

value than investment B, assuming that the two investments are of similar risk, because investment A realizes the majority of its cash flow in early years. Investment B does not realize substantial cash flow until late in the life of the investment. Both investments have the same payback period and require the same initial investment (Table 2). However, investment A returns 50% of the invested capital in 1 year, but investment B returns only 5% of the invested capital in the first year and has a much different overall pattern of returns then investment A.

Another problem with payback is that there is no recognition of cash flow beyond the payback period. Investments A and/or B (Table 2) could require substantial reinvestment or realize a major return in year 11 and beyond, which would affect the valuation of the investment. Payback is only concerned with the payback of the initial investment, not any subsequent cash flows.

Frequently, small business owners use payback as a risk indicator or establish a maximum payback period as a cut-off point in evaluating investments. These practices are often justified due to the limited availability of capital to the small businessman.

Payback is used as a risk indicator to measure how long the invested capital is at risk or tied-up in the investment. Table 2 illustrates how two investments can have the same payback period, but radically different cash flows. Payback would indicate that the $10,000 investment for investments A and B (Table 2) is at risk for 10 years, but that is hardly the case. Investment A returns 50% of the invested capital in the first year, so this amount can no longer be considered at risk, even though the full $10,000 isn't returned until the tenth year.

Discounted Cash Flow

Analysis of the initial investment and future cash flows can be accomplished with the use of discounted cash flow techniques combined with the capital budgeting process. Discounted cash flow is a means of comparing investments with different cash flows in different future periods. The future cash flows are discounted or reduced in value to reflect the time value of money associated with actually receiving cash flows as they extend farther into the future. By discounting the cash flows, investments can then be compared on the basis of what they are worth today. Determining what a future cash flow is worth today by discounting it back to the present establishes the present value of the future cash flow. The concept of present value will be elaborated on, as it is central to understanding discounted cash flow.

Capital budgeting is the process of generating investment proposals, estimating the investments' performance, and selecting investments based on acceptance criteria. Generally, capital budgeting is considered in relation to expenditures on assets whose returns are expected to extend beyond 1 year.

Discounting and the Discount Rate: Discounting is easy to understand if one first thinks of compound interest. If $100 is placed in a savings account for 1 year at 5% interest, there will be $105 in the account at the end of the year. At the end of the second year there will be $110.25, assuming annual compounding, because there is $5 interest earned on the original $100, but there is also 5% or $0.25 earned on the first year's interest. In the same manner, the balance of the account at any year in the future can be estimated. Discounting is the opposite of compounding.

Based on the estimated performance of an investment, the future net cash flow is estimated for each year of the investment's life. Using discounted cash flow, the future cash flow estimates are discounted back to the present at the discount rate. The discount rate is a specific percentage by which future cash flows are increasingly reduced in value for each year that the cash flow extends into the future.

To reduce the value of the future cash flows, discount factors corresponding to the percent discount rate are used. For example, in Figure 1, the discount factor at a 15% discount rate for a cash flow occurring 1 year from today is 0.8696. The factor at a 15% discount rate for a cash flow occurring 2 years from today is 0.7516. This means that if a grower places a value of 15% on money, he would be willing to pay approximately $0.87 for $1, 1 year from today and approximately $0.76 for $1, 2 years from today. Similarly, the present value of any future cash flow or, as with energy conservation investments, the present value of future energy savings can be determined by multiplying the cash flow by the discount factor corresponding to the percent discount rate and year in which the cash flow occurs.

Figure 1 illustrates the discounting process. In this figure, all estimated future cash flows are discounted back to the present so that all dollars can be thought of as if they are being realized today.[2] In other words, today's value or the present value of future cash flow is being determined. If a relatively high discount rate is used, future cash flows are of comparatively less relative value today than if a lower discount rate is used.

The discount rate can represent any of several possible alternatives. Frequently, the discount rate

[2]Discounted cash flow assumes that the cash flow for any given year occurs in one lump sum at the end of the year. Energy savings will be realized on close to a year-round basis, but at worst this assumption will cause only small rounding errors. Discount rate factors can be interpolated between years if there are significant mid-year or quarterly cash flows, but because of the variable nature of month-to-month energy savings, little would be gained by doing so.

used by a given business is the cost of capital for the business. For example, if an after-tax cost of capital of 15% has been determined, the business would use a 15% discount rate in evaluating proposed investments. Many businessmen feel that at a minimum an investment must have a rate of return at least equal to the firm's cost of capital. The cost of capital is the firm's total cost of using funds from both debt and equity sources.

The discount rate can also represent the minimum return on investment that the firm feels is acceptable compensation for the riskiness of the given investment. This rate may be more than the cost of capital rate because businesses frequently add a risk premium when evaluating investments. The cost of capital can be used as a base rate of return, which is then upwardly adjusted for the perceived risk of the proposed investment. The risk adjusted rate then becomes the discount rate used to discount the investment.

The discount rate can also represent the rate at which the business can obtain capital to finance the investment or it can be the opportunity cost associated with the funds used for the investment. An after-tax discount rate of 15%, representing the cost of capital for a hypothetical greenhouse crop production business, has been used in the valuation of the savings realized with the energy conservation investments analyzed later.

Figure 2 illustrates the relationship between the discount rate, present value interest factor, and time in the valuation of future cash flows. In time period 0, which is the present, the present value factor is 1.00 because the present value of a cash flow today is

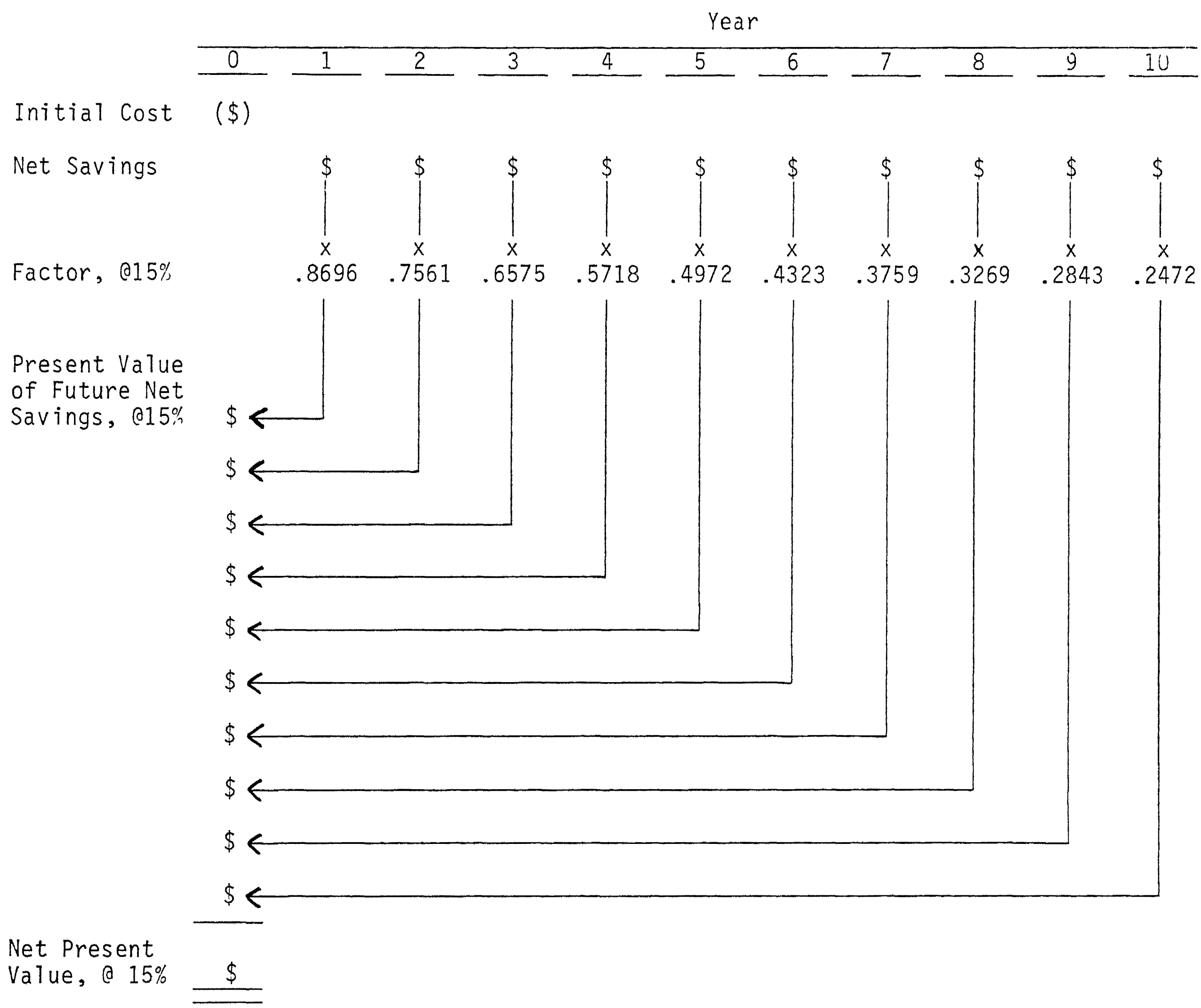

FIG. 1.—Illustration of the discounting process.

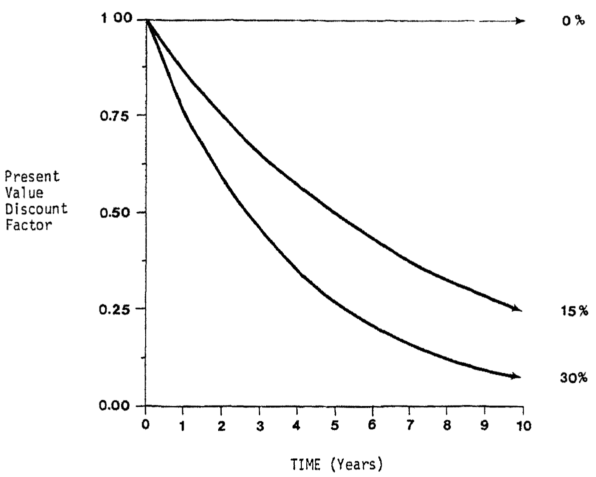

FIG. 2.—Relationship between discount rate, present value discount factor, and time in the valuation of future cash flows.

Source: Weston, J. Fred and Eugene F. Brigham. 1978. Managerial Finance, Sixth Ed. The Dryden Press, Hinsdale, Ill.

the dollar amount of the cash flow. Similarly, if a 0% discount rate is used, which means the investor places no time value on money, the present value factor will be 1.00 over any time period. The present value of any future cash flow at a 0% discount rate is the dollar amount of the cash flow.

The higher the discount rate used, the lower the present value of future cash flow. In Figure 2, the present value interest factor drops off very quickly over time at a 15% discount rate. As the discount factor becomes smaller, the corresponding cash flow that is multiplied by the discount factor is also reduced. For example, at a 15% discount rate, a cash flow occurring in the fifth year of a given investment is worth approximately $0.50 in present value dollars for each fifth year future dollar. By the tenth year, the factor has dropped to 0.2472, so each dollar in the tenth year is worth approximately $0.25. At a 30% discount rate (Figure 2), the present value factors become smaller even more rapidly than at 15%.

Present Value: Present value is a discounted cash flow technique. To determine present value, projected future cash flow is multiplied by the discount rate factor that corresponds to the discount rate for the year in which the cash flow occurs. Each year's discounted cash flow is summed to determine the present value of all future cash flow, which is the present value of the investment. The present value indicates what the future stream of cash flow is worth today. In other words, investors should be indifferent between receiving $0.87 today or $1, 1 year from today if 15%, the discount rate, is perceived as being acceptable compensation, since $0.87 is what $1 is worth 1 year from today at that rate.

Net Present Value: The net present value of an investment, determined by subtracting the initial capital outlay from the present value of the future cash flow (Figure 1), is a direct measure of the increase in net worth that a business will realize by choosing that investment. Based on financial considerations, any investment with a negative net present value is not acceptable because it will decrease a business' net worth. However, if the objective of making a given investment is prestige or convenience or if the investment is required for health or safety reasons, for example, a negative net present value does not necessarily exclude an investment from further consideration.

An investment with a positive net present value is acceptable, while an investment with a zero net present value is a marginal or break-even investment. When comparing several investments, the one with the highest net present value at the discount rate or cost of capital used will increase an organization's net worth the most, and is therefore the best investment.[3]

Internal Rate of Return: The internal rate of return is another widely used discounted cash flow valuation technique. The internal rate of return should be thought of as the break-even discount rate because it is the discount rate that equates the initial investment cost with the present value of the projected cash returns. If the internal rate of return is above the discount rate used in calculating the net present value, the investment is acceptable. If the internal rate of return is below the discount rate, the investment is unacceptable.

The net present value and internal rate of return will normally give identical answers with respect to the accept or reject decision. However, calculating the internal rate of return determines the actual rate at which the invested money is compounding and shows the range of discounted rates over which the investment is acceptable and unacceptable.[4]

Figure 3 illustrates the relationship between net present value, discount rate, and internal rate of return. The example investment has a positive net present value of $60,000 at a discount rate of 15%. As the investor places a higher value on the investment, the net present value decreases. At a 50% discount rate, the investment has a zero net present value. Therefore, 50% is the internal rate of return for this hypothetical investment. At discount rates

[3]Whether the best investment, as measured by net present value, can be made will depend on the necessary capital being available. This assumes an unlimited capital market. In a market where the capital supply is restricted, the small businessman may not be able to obtain adequate outside capital, which would limit investment choices, regardless of the net present values of the investments examined.

[4]When mutually exclusive investments are being evaluated, the two measures may give conflicting accept or reject signals. In these cases, net present value should take precedence over the internal rate of return.

higher than 50%, the investment has an increasingly negative net present value. Figure 3 indicates that the investment is acceptable at discount rates of up to 49.99% because it has a positive net present value at all discount rates up to 50%. Whether this investment is more desirable than another would depend on many of the criteria discussed, including the net present value of other alternative investments.

Profitability Index: A third discounted cash flow valuation technique is the profitability index. The profitability index is a measure of the number of present value dollars returned for each dollar originally invested. For example, an investment with a profitability index of 5 is returning $5, in present value terms, for each dollar initially invested. The profitability index is computed by dividing the present value of all projected net cash flows by the initial investment. Criteria for the profitability index are similar to net present value in that an investment with a profitability index of less than 1 is unacceptable. A profitability index of 1 indicates a marginal or break-even investment, and a profitability index of more than 1 means that the investment is returning more than $1 in the future for each dollar initially invested.

All of the investment evaluation criteria influence investment analysis and should be considered before making any given investment. In addition to the quantitative discounted cash flow valuation and financial measures discussed, the subjective factors and requirements unique to each organization should be considered. A complete investment analysis will help lead to a rational investment decision.

The following is a discussion and analysis of several energy conservation investments using capital budgeting and the discounted cash flow techniques discussed. Costs, projected annual cash flow, present values, net present values, internal rates of return, profitability indices, and average percent net energy dollar savings over a 10-year period are presented for greenhouse double-layer, air-inflated polyethylene over glass, greenhouse internal curtains, and glass lap sealants, in addition to a ranking of these energy conservation investments considering both natural gas and #2 oil as heat sources.

DISCOUNTED CASH FLOW ANALYSES OF SELECTED ENERGY CONSERVATION INVESTMENTS

Double-Layer, Air-Inflated Polyethylene Over Glass

Double-poly offers significant fuel savings in greenhouse crop production. Researchers at the Ohio Agricultural Research and Development Center

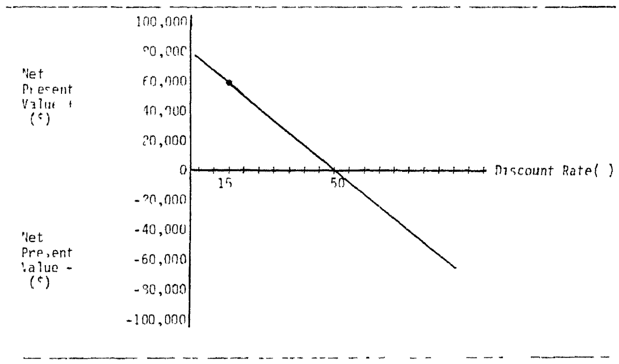

FIG. 3.—Relationship between net present value, discount rate, and internal rate of return.

(OARDC) have determined that a double-layer of air-inflated polyethylene over glass can reduce energy use by approximately 57% on an annual basis (4).[5] The exact reduction for a given greenhouse will vary due to several factors, including the severity of the climate outside the greenhouse and the physical condition of the greenhouse. Relatively new greenhouses in good condition will probably not realize energy savings as substantial as those realized when double-poly is used on older greenhouses. Gross reduction in energy use frequently averages 50% (7).

The double-poly cover over glass reduces light transmission by approximately 18%, but tends to diffuse the light similar to fiberglass coverings (4). Reduced light transmission is a factor only with certain crops. For instance, double-poly over glass can be excellent for foliage plants and, with the use of growth regulators, may be for flowering plant production (1). Crops requiring a high light intensity, such as cut flowers and tomatoes, are the most affected by the light reduction. Because of the double-poly cover, a loss in tomato yield of at least 6% has been estimated (4). Reduced fuel use may or may not compensate for losses in yield and/or quality with certain crops. The trade-off between fuel savings and reduced yield will have to be examined on a crop by crop basis.

Double-poly over glass requires a moderate capital investment in comparison to other energy conservation techniques. Initially, there is a one-time expense for extruded aluminum fasteners, in addition to the polyethylene, at a total cost of approximately $28,314/acre[6], or $0.65/ft² including labor.[7] Polyethylene that is resistant to ultraviolet degradation must be replaced on an average of every 2 years. Therefore there is a recurring expense of approxi-

[5]57 % fuel saving was realized with the entire greenhouse covered with double-poly. Savings realized with less than the entire greenhouse covered may be somewhat less.
[6]Based on ground area covered.
[7]Average installed cost/ft² of area covered.

mately $0.15/ft^2, including labor, at current costs (4). Costs have been inflated at 10% per year to include the effects of inflation in the evaluation of all the energy conservation investments. The expense and availability of labor for the reinstallation of the poly are factors to consider in the use of the double-poly cover.

Discounted cash flow analysis (Tables 3 and 4) of the double-poly energy conservation technique demonstrates that it is the most attractive investment of those examined at a 15% discount rate. Double-poly greatly reduces energy use with only a moderate capital investment. Average net energy dollar savings of approximately 45% and 42% will be realized over the projected 10-year period for greenhouses heated with #2 oil and natural gas, respectively. The net present value of the projected dollar savings, internal rates of return, and profitability indices for double-poly on greenhouses heated with #2 oil and natural gas are $184,515 and $87,878, 116.4% and 66.5%, 7.52 and 4.10, respectively.

Of the conservation techniques analyzed, all three valuation measures for both fuels are the highest for double-poly. Use of double-poly on a greenhouse heated with #2 fuel oil or natural gas will increase the net worth of a business by $184,515/acre or $87,878/acre over the projected period, respectively. The internal rates of return indicate that double-poly would be an acceptable investment at discount rates up to approximately 116% and 66% for greenhouses heated with #2 oil and natural gas, respectively. The internal rates of return indicate a great deal of flexibility in the discount rate used. For greenhouses heated with #2 oil and natural gas, the double-poly investment is returning $7.52 and $4.10 in present value dollars for each dollar initially invested, respectively.

This investment also offers the greatest financial flexibility because of the regular reinvestment in poly. Each year that the poly must be replaced presents another opportunity to reevaluate the old and new investment alternatives before recommitting the capital for new poly. Of the investments analyzed, no other offers the same degree of financial flexibility, although some flexibility may be lost in terms of the types of crops that can be produced under a double-poly cover.

Table 11 presents a summary of all of the valuation measures determined for each investment for both #2 oil and natural gas. The reader may wish to refer to this table periodically while reading the text.

Internal Curtains

Internal curtains, also called heat sheets, heat curtains, and thermal blankets, are another major technique now available for greenhouse energy conservation. An internal curtain is a fabric that acts as an insulation sheet at night. The main thermal effect of the curtain is the addition of the two extra surfaces for resistance to heat flow. The curtain is extended from gutter to gutter, truss to truss, gutter to ridge, or end to end in quonset structures. Average annual gross reduction in energy use is approximately 33%, assuming a tight seal and proper fabric selection (8). Higher percentage savings have been realized in individual situations. Internal curtains are most effective and most easily installed in greenhouses with large clear span areas, so they do not have as wide an application as double-poly.

Many types of materials are available for internal curtains. The type of fabric used has a direct bearing on the energy saving realized. The material must be nonporous and have a reflective backing for maximum heat retention. Porous and nonporous materials with reflective backings are currently available. While some growers have also used shade cloth as an internal curtain, the energy-saving value of the internal curtain will not be as great as with fabrics selected specifically for use as an internal curtain. The best internal curtain material available is not the best shading material and vice versa.

It would be difficult to place a general economic value on intermittent use of an internal curtain for photoperiod control or for currently used shade cloth as an internal curtain, but double use of the cloth is an important factor that growers may want to consider in evaluating an internal curtain system. A 5-year life of internal curtain fabric is considered a reasonable estimate (10).

The cost of an internal curtain system varies widely depending on the given facility and materials, but $1.25/ft^2 or $54,450/acre[8] is considered to be the average investment for an installed and operating system, including labor. Fully mechanized systems requiring substantial structural modification may cost more than $1.25/ft^2, while unmechanized systems requiring comparatively few structural changes may cost less.

Whether to install internal curtains requires many cost considerations. In addition to the cost of materials and labor, modification of the heating system, water lines, and lights may be additional costs. The installation of the internal curtain from gutter to gutter will also change the classification, valuation, and insurance premiums for the greenhouse. Currently, Florists' Mutual, Inc. is levying a 15% surcharge to the extended coverage rate for a gutter to gutter internal curtain installation in a glass green-

[8]Calculated using 43,560 ft^2 at $1.25/ft^2, so cost/acre is based on ground area covered.

TABLE 3.—Annual Net Energy Savings ($) per Acre with the Use of Double-Layer, Air-Inflated Polyethylene Over Glass on Greenhouses Heated with No. 2 Fuel Oil.

	Year										
	0	1	2	3	4	5	6	7	8	9	10
Initial installation cost/acre*	$—28,314										
Energy cost/acre/year†‡ (60° F nights)		65,166	71,682	78,851	86,736	95,409	104,950	115,445	126,990	139,689	153,657
Average price/gallon‡ **		.75	.82	.91	1.00	1.10	1.20	1.33	1.46	1.60	1.76
Energy cost/acre/year, @ 50% reduction††		32,583	35,841	39,426	43,368	47,705	52,475	57,723	63,495	69,845	76,829
			35,841		43,368		52,475		63,495		
Polyethylene replacement cost/acre‡ ‡‡			—7,906		—9,566		—11,575		—14,006		
Net $ savings/acre/year***		32,583	27,935	39,426	33,802	47,705	40,900	57,723	49,489	69,845	76,829
Net percent $ savings/acre/year		50%	39%	50%	39%	50%	39%	50%	39%	50%	50%
Average percent net $ savings/acre/year						45.6%					
Total net $ savings/acre	$ 476,237.00										
PV of total net $ savings/acre, @ 15% discount rate	$ 212,829.09										
NPV of total net $ savings/acre, @ 15% discount rate	$ 184,515.09										
Internal rate of return	116.36%										
Profitability index	7.52										

*$0.65/ft², including labor. Only roof area covered.
†2 gallons/ft²/year @ $0.68/gallon or $59,242 in year 0.
‡10%/annum inflation.
**$0.68/gallon in year 0.
††50% average fuel use reduction with double-poly over glass (gutter to ridge to gutter).
‡‡$0.15/ft², including labor, in year 0.
***Loss in yield and/or quality, if any, not considered.

TABLE 4.—Annual Net Energy Savings ($) per Acre with the Use of Double-Layer, Air-Inflated Polyethylene Over Glass on Greenhouses Heated with Natural Gas.

	Year										
	0	1	2	3	4	5	6	7	8	9	10
Initial installation cost/acre*	$—28,314										
Energy cost/acre/year† ‡ (60° F nights)		38,237	42,061	46,267	50,893	55,983	61,581	67,739	74,513	81,964	90,161
Average price/MCF‡**		3.14	3.45	3.79	4.17	4.59	5.05	5.55	6.11	6.72	7.39
Energy cost/acre/year, @ 50% reduction††		19,119	21,031	23,134	25,447	27,992	30,791	33,870	37,257	40,982	45,081
			21,031		25,447		30,791		37,257		
Polyethylene replacement cost/acre‡ ‡‡			—7,906		—9,566		—11,576		—14,006		
Net $ savings/acre/year***		19,119	13,125	23,134	15,881	27,992	19,216	33,870	23,251	40,982	45,081
Net percent $ savings/acre/year		50%	31.2%	50%	31.2%	50%	31.2%	50%	31.2%	50%	50%
Average percent net $ savings/acre/year						42.5%					
Total net $ savings/acre	$ 261,651.00										
PV of total net $ savings/acre, @ 15% discount rate	$ 116,191.93										
NPV of total net $ savings/acre, @ 15% discount rate	$ 87,877.93										
Internal rate of return	66.50%										
Profitability index	4.10										

*$0.65/ft², including labor. Only roof area covered.
†0.280 MCF/ft²/year @ $2.85/MCF or $34,761/acre in year 0.
‡10%/annum inflation.
**$2.85/MCF in year 0.
††50% average fuel use reduction with double-poly over glass (gutter to ridge to gutter).
‡‡$0.15/ft², including labor, in year 0.
***Loss in yield and/or quality, if any, not considered.

TABLE 5.—Annual Net Energy Savings ($) per Acre with the Use of Internal Curtains in Greenhouses Heated with No. 2 Fuel Oil.

	Year 0	1	2	3	4	5	6	7	8	9	10
Initial installation cost/acre*	$—54,450										
Energy cost/acre/year† ‡ (60° F nights)		65,166	71,682	78,851	86,736	95,409	104,950	115,445	126,990	139,689	153,657
Average price/gallon‡ **		.72	.82	.91	1.00	1.10	1.20	1.33	1.46	1.60	1.76
Energy cost/acre/year, @ 33% reduction††		43,661	48,027	52,830	58,113	63,924	70,317	77,348	85,083	93,592	102,950
						31,485					
Fabric replacement cost/acre‡ ‡‡						—29,465					
Net $ savings/acre/year***		21,505	23,655	26,021	28,623	2,020	34,663	38,097	41,907	46,097	50,707
Net percent $ savings/acre/year		33%	33%	33%	33%	2.1%	33%	33%	33%	33%	33%
Average percent net $ savings/acre/year		29.9%									
Total net $ savings/acre	$ 313,265.00										
PV of total net $ savings/acre, @ 15% discount rate	$ 139,697.19										
NPV of total net $ savings/acre, @ 15% discount rate	$ 85,247.19										
Internal rate of return	43.49%										
Profitability index	2.57										

*$1.25/ft², including labor.
†2 gallons/ft²/year @ $0.68/gallon or $59,242 in year 0.
‡10%/annum inflation.
**$0.68/gallon in year 0.
††33% average fuel use reduction with internal curtains (gutter to gutter).
‡‡$0.42/ft², including labor, in year 0.
***Loss in yield and/or quality and cost of insurance surcharge, and/or cost of modifications, if any, not considered.

TABLE 6.—Annual Net Energy Savings ($) per Acre with the Use of Internal Curtains in Greenhouses Heated with Natural Gas.

	Year 0	1	2	3	4	5	6	7	8	9	10
Initial installation cost/acre*	$—54,450										
Energy cost/acre/year† ‡ (60° F nights)		38,237	42,061	46,267	50,893	55,983	61,581	67,739	74,513	81,964	90,161
Average price/MCF‡ **		3.14	3.45	3.79	4.17	4.59	5.05	5.55	6.11	6.72	7.39
Energy cost/acre/year, @ 33% reduction††		25,619	28,181	30,999	34,098	37,509	41,259	45,385	49,924	54,916	60,408
						18,474					
Fabric replacement cost/acre‡ ‡‡						—29,465					
Net $ savings/acre/year***		12,618	13,880	15,268	16,795	—10,991	20,322	22,354	24,589	27,048	29,753
Net percent $ savings/acre/year		33%	33%	33%	33%	—19.6%	33%	33%	33%	33%	33%
Average percent net $ savings/acre/year		27.7%									
Total net $ savings/acre	$ 171,636.00										
PV of total net $ savings/acre, @ 15% discount rate	$ 75,915.39										
NPV of total net $ savings/acre, @ 15% discount rate	$ 21,465.39										
Internal rate of return	22.84%										
Profitability index	1.39										

*$1.25/ft², including labor.
†0.280 MCF/ft²/year @ $2.85/MCF or $34,761/acre in year 0.
‡10%/annum inflation.
**$2.85/MCF in year 0.
††33% average fuel use reduction with internal curtains (gutter to gutter).
‡‡$0.42/ft², including labor, in year 0.
***Loss in yield and/or quality and cost of insurance surcharge and/or cost of modifications, if any, not considered.

house (5). Polyethylene houses are not subject to this surcharge.

Discounted cash flow analysis (Tables 5 and 6) of internal curtains shows that they are an acceptable investment at a 15% discount rate for greenhouses heated with either #2 oil or natural gas. The initial capital commitment is comparatively high and directly influences the economic feasibility of this investment. Businesses, regardless of size, do not have unlimited capital or credit, so the size of the initial investment in relation to the benefits derived is critical.

Currently available fabrics have an estimated life of 5 years, so the fabric will need to be replaced at the end of the fifth year in the projected 10-year period. At a current estimated cost of $\$0.42/ft^2$, including labor (10), the fabric replacement cost reduces the value of energy savings to 2.1% in the fifth year for greenhouses heated with #2 oil. For greenhouses heated with natural gas, the fabric replacement cost exceeds the value of energy savings in the fifth year by 19.6%. This results in a negative cash flow in the fifth year.

The net energy dollar savings over the projected 10-year period are 29.9% and 27.7% for greenhouses heated with #2 oil and natural gas, respectively. The net percent dollar saving for internal curtains in greenhouses heated with natural gas is lower than the net percent dollar saving for greenhouses heated with #2 oil because the fabric replacement cost is a greater percentage of total heating cost using natural gas than using oil.

The net present value of the projected dollar savings, internal rate of return, and profitability index for internal curtains in greenhouses heated with #2 oil and natural gas are $85,247 and $21,465, 43.49% and 22.84%, 2.57 and 1.39 respectively. Of the conservation techniques analyzed, internal curtains ranked third in net present value and fourth in internal rate of return and profitability index for greenhouses heated with #2 oil. Internal curtains ranked fourth in net present value and third in internal rate of return and profitability index for greenhouses heated with natural gas (Table 11).

The net present value of energy savings from internal curtains is less than half and less than one-fourth of the net present value of energy savings from double-poly on greenhouses heated with #2 oil and natural gas, respectively. Internal curtains require almost twice the initial investment that double-poly requires. As indicated by the internal rates of return, the range of discount rates at which internal curtains are an acceptable investment is considerably reduced in comparison to double-poly. At discount rates higher than 43.49% and 22.84% for greenhouses heated with #2 oil and natural gas, respectively, internal curtains would not be an acceptable investment at the cost and percent energy saving levels used in this analysis.

The relative marginal profitability of internal curtains is further established by the profitability indices in comparison to the profitability indices for the other investments analyzed. The insurance surcharge and cost of equipment or structural modifications, if any, have not been considered.

Based solely on this financial exercise, internal curtains do not currently appear to warrant the large capital commitment required in comparison to the other investments analyzed. Other factors, such as type of crop being produced and double-use of the curtains as shade cloth, will have a bearing on the decision to invest in internal curtains. If new greenhouses are designed for and constructed with internal curtains, the relative economic unattractiveness of internal curtains would probably change.

The combination of double-poly and internal curtains is an acceptable investment at a 15% discount rate and is, in fact, more attractive on several bases than internal curtains alone (Tables 7 and 8). The combined initial expense of the two investments is $82,760/acre at the costs used previously for each investment by itself. The combination offers an estimated 55% gross reduction in energy use. Because of the replacement cost of poly in years 2, 4, 6, and 8, the net energy dollar saving in those years is approximately 44%. The curtain fabric must be replaced at the end of year 5 which, because of the high fabric replacement cost, causes the net energy dollar saving to drop to 24% in that year. The net energy dollar saving over the projected 10-year period is 47.5%. The net present value of the projected dollar savings, internal rate of return, and profitability index for this combination of investments for greenhouses heated with #2 oil and natural gas are $138,803 and $32,500, 45.03% and 22.68%, 2.68 and 1.39, respectively.

Although this investment is acceptable, a glaring problem should be apparent. The combination offers almost the same net energy dollar savings as double-poly at almost three times the initial investment. Furthermore, the net present values of the combination are considerably less than those of double-poly. The profitability indices indicate that only $2.68 and $1.39 present value dollars are being returned for each dollar initially invested, in comparison to $7.52 and $4.10 for double-poly for greenhouses heated with #2 oil and natural gas, respectively.

When evaluating combinations of energy conservation techniques, it is important to consider the cost of incremental or additional savings vs. the savings derived from each method alone. Incremental

TABLE 7.—Annual Net Energy Savings ($) per Acre with the Use of Double-Layer, Air-Inflated Polyethylene Over Glass and Internal Curtains in Greenhouses Heated with No. 2 Fuel Oil.

	Year										
	0	1	2	3	4	5	6	7	8	9	10
Initial installation cost/acre*	$—28,314* —54,450†										
	$—82,760										
Energy cost/acre/year† ‡ (60° F nights)		65,166	71,682	78,851	86,736	95,409	104,950	115,445	126,990	139,689	153,657
Average price/gallon** ††		75	82	91	1 00	1 10	1 20	1 33	1.46	1 60	1 76
Energy cost/acre/year, @ 50% reduction‡‡		32,583	35,841	39,426	43,368	47,705	52,475	57,723	63,495	69,845	76 829
Energy cost/acre/year, @ 10% additional reduction***		29,325	32,257	35,483	39,031	42,935	47,228	51,951	57,146	62,861	69,146
			39 425		47,705	52,474	57,722		69,844		
Polyethylene and fabric replacement cost/acre** †††			—7,906		—9,566	—29,465	—11,575		—14,006		
Net $ savings/acre/year‡‡‡		35,841	31,519	43 368	38,139	23,009	46,147	63,494	55,838	76,828	84,511
Net percent $ savings/acre/year		55%	44%	55%	44%	24%	44%	55%	44%	55%	55%
Average percent net $ savings/acre/year						47 5%					
Total net $ savings/acre	$ 498,694 00										
PV of total net $ savings/acre, @ 15% discount rate	$ 221,562 83										
NPV of total net $ savings/acre, @ 15% discount rate	$ 138,802 83										
Internal rate of return	45 03%										
Profitability index	2 68										

*$0 65/ft², including labor Only roof area covered
†$1 25/ft², including labor
‡2 gallons/ft²/year @ $0 68/gallon or $59,242 in year 0.
**10%/annum inflation
††$0 68/gallon in year 0
‡‡50% average fuel use reduction with double-poly over glass (gutter to ridge to gutter)
***Estimated 10% additional fuel use reduction with internal curtains (gutter to gutter)
†††$0 15/ft² and $0 42/ft², including labor, respectively in year 0
‡‡‡Loss in yield and/or quality and cost of insurance surcharge and/or cost of modifications, if any, not considered

TABLE 8.—Annual Net Energy Savings ($) per Acre with the Use of Double-Layer, Air-Inflated Polyethylene Over Glass and Internal Curtains in Greenhouses Heated with Natural Gas.

	Year										
	0	1	2	3	4	5	6	7	8	9	10
Initial installation cost/acre	$—28,314* —54,450† $—82,760										
Energy cost/acre/year‡ ** (60° F nights)		38,237	42,061	46,267	50,893	55,983	61,581	67,739	74,513	81,964	90,161
Average price/MCF** ††		3.14	3.45	3.79	4.17	4.59	5.05	5.55	6.11	6.72	7.39
Energy cost/acre/year, @ 50% reduction‡‡		19,119	21,031	23,134	25,447	27,992	30,791	33,870	37,257	40,982	45,081
Energy cost/acre/year, @ 10% additional reduction***		17,207	18,928	20,821	22,902	25,193	27,712	30,483	33,531	36,884	40,573
			23,133		27,991	30,790	33,869		40,982		
Polyethylene and fabric replacement cost/acre** †††			—7,906		—9,566	—29,465	—11,575		—14,006		
Net $ savings/acre/year‡‡‡		21,030	15,227	25,446	18,425	1,325	22,294	37,256	26,976	45,080	49,588
Net percent $ savings/acre/year		55%	36.2%	55%	36.2%	2.4%	36.2%	55%	36 2%	55%	55%
Average percent net $ savings/acre/year						42.2%					
Total net $ savings/acre	$ 262,647.00										
PV of total net $ savings/acre, @ 15% discount rate	$ 115,259.90										
NPV of total net $ savings/acre, @ 15% discount rate	$ 32,499.90										
Internal rate of return	22.68%										
Profitability index	1.39										

*$0.65/ft², including labor. Only roof area covered.
†$1.25/ft², including labor.
‡0.280 MCF/ft²/year @ $2.85/MCF or $34,761/acre in year 0.
**10%/annum inflation.
††$2.85/MCF in year 0.
‡‡50% average fuel use reduction with double-poly over glass (gutter to ridge to gutter).
***Estimated 10% additional fuel use reduction with internal curtains (gutter to gutter).
†††$0.15/ft² and $0.42/ft², including labor, respectively in year 0.
‡‡‡Loss in yield and/or quality and cost of insurance surcharge and/or cost of modifications, if any, not considered.

TABLE 9.—Annual Net Energy Savings ($) per Acre with the Use of Glass Lap Sealants on Greenhouses Heated with No. 2 Fuel Oil.

	Year										
	0	1	2	3	4	5	6	7	8	9	10
Initial installation cost/acre*	$—15,246										
Energy cost/acre/year† ‡ (60° F nights)		65,166	71,682	78,851	86,736	95,409	104,950	115,445	126,990	139,689	153,657
Average price/gallon‡ **		.75	.82	.91	1.00	1.10	1.20	1.33	1.46	1.60	1.76
Energy cost/acre/year, @ 15% reduction††		55,391	60,930	67,023	73,726	81,098	89,208	98,128	107,942	118,736	130,608
Net $ savings/acre/year‡‡		9,775	10,752	11,828	13,010	14,311	15,742	17,317	19,048	20,953	23,049
Net percent $ savings/acre/year		15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
Average net percent $ savings/acre/year						15%					
Total net $ savings/acre	$ 155,785.00										
PV of total net $ savings/acre, @ 15% discount rate	$ 70,156.90										
NPV of total net $ savings/acre, @ 15% discount rate	$ 54,910.90										
Internal rate of return	73.27%										
Profitability index	4.60										

*$0.35/ft², including labor.
†2 gallons/ft²/year @ $0.68/gallon or $59,242 in year 0.
‡10%/annum inflation.
**$0.68/gallon in year 0.
††15% average fuel use reduction with glass lap sealant.
‡‡Loss in yield and/or quality and cost of modifications, if any, not considered.

TABLE 10.—Annual Net Energy Savings ($) per Acre with the Use of Glass Lap Sealants on Greenhouses Heated with Natural Gas.

	Year										
	0	1	2	3	4	5	6	7	8	9	10
Initial installation cost/acre*	$—15,246										
Energy cost/acre/year† ‡ (60° F nights)		38,237	42,061	46,267	50,893	55,983	61,581	67,739	74,513	81,964	90,161
Average price/MCF‡ **		3.14	3.45	3.79	4.17	4.59	5.05	5.55	6.11	6.72	7.39
Energy cost/acre/year, @ 15% reduction††		32,501	35,752	39,327	43,259	47,586	52,344	57,578	63,336	69,669	76,637
Net $ savings/acre/year‡‡		5,736	6,309	6,940	7,634	8,397	9,237	10,161	11,177	12,295	13,524
Net percent $ savings/acre/year		15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
Average percent $ savings/acre/year						15%					
Total net $ savings/acre	$ 91,410.00										
PV of total net $ savings/acre, @ 15% discount rate	$ 41,166.08										
NPV of total net $ savings/acre, @ 15% discount rate	$ 25,920.08										
Internal rate of return	45.01%										
Profitability index	2.70										

*$0.35/ft², including labor.
†0.280 MCF/ft²/year @ $2.85/MCF or $34,761/acre in year 0.
‡10%/annum inflation.
**$2.85/MCF in year 0.
††15% average fuel use reduction with glass lap sealant.
‡‡Loss in yield and/or quality and cost of modifications, if any, not considered.

savings may come at a high cost because they will frequently be only a fraction of the percentage energy savings realized when a technique is used alone, but the same investment will still be required.

Glass Lap Sealants

Glass lap sealants are clear silicone compounds which are injected between the glass laps and reduce energy use by reducing infiltration. Energy savings with the use of lap sealants has ranged from 5% to 40% annually, depending on the condition of the greenhouse, but 15% is estimated as average (2, 9). One silicone compound on the market is guaranteed for 10 years, including labor for reinstallation, so there are no other costs associated with this technique. Glass lap sealants offer other advantages which include no glass slippage, negligible light reduction, and longer retention of supplemental CO_2.

An investment in glass lap sealants is attractive because of a comparatively low initial investment and an average net energy dollar savings of 15% (Tables 9 and 10). The net present value of the projected dollar savings, internal rate of return, and profitability index for glass lap sealants on greenhouses heated with #2 oil and natural gas are $54,911 and $25,920, 73.27% and 45.01%, 4.60 and 2.70, respectively.

At an initial average installation expense of approximately $15,000/acre or $0.35/ft^2, including labor, lap sealants offer a comparatively high net present value considering the moderate investment. This is illustrated by the profitability indices which are the second highest of the investments examined, indicating a comparatively high present value dollar return for each dollar initially invested despite the low percent actual net savings realized. The internal rates of return of 73.27% and 45.01% for lap sealants on greenhouses heated with #2 oil and natural gas, respectively, indicate that lap sealants would be a profitable investment at a wide range of discount rates.

The major drawback of an investment in lap sealants is that it is the least flexible. Once the sealant has been applied, the invested capital has been permanently committed. There is no opportunity for reevaluation and redeployment of the invested capital if new needs or technological advances should develop. Thorough investment capital and cash flow planning can alleviate at least some of the concern over inflexibility.

A potentially attractive combination of conservation techniques would be to use double-poly and lap sealants. Double-poly used on the north roof area and sides and lap sealants used on the south roof area might maximize the value of each investment, while minimizing light loss from the use of double-poly.

Figures 4 and 5 illustrate the relative position and attractiveness of an investment in double-poly, internal curtains, and glass lap sealants in relation to the valuation measures presented for greenhouses heated with #2 oil and natural gas, respectively. Double-poly has the highest net present value and the highest internal rate of return, which indicates that it is an acceptable investment over the widest range of discount rates.

Figure 4 also indicates that if sufficient capital is available, the second highest energy dollar savings will be realized with internal curtains and the third highest with lap sealants for growers using #2 oil. However, since double-poly offers a considerably higher return for approximately one-half the investment, the rational investor would not choose internal curtains.

If capital availability is restricted to less than the amount required for double-poly, lap sealants become the second-best investment because of the relatively low investment and relatively high present value dollar return for each dollar invested. The incremental dollar savings achieved by additional investment must be considered in relation to the total investment required.

Figure 5 indicates the same relative ranking of the investments as indicated by Figure 4. The dollar amounts are different because total fuel cost is less with natural gas than with #2 oil, but gross percent energy conservation is the same regardless of heat source. Net percent energy dollar savings are smaller when using natural gas because material replacement costs are a greater percent of total fuel cost, which depresses the net percent dollar savings. Subject to capital availability and crop considerations, return will be maximized with double-poly. An investment in lap sealants will realize the second highest return and internal curtains will realize the lowest return.

SUMMARY

If greenhouse crop production facilities are to remain profitable, a concerted effort must be made to control energy and all other production costs. At a 10% annual inflation rate, the cost of heating an acre of greenhouses annually with #2 fuel oil or natural gas will be more than $150,000 or $90,000 before 1990, respectively. The cost of energy does not have to account for 20% of production costs because the conservation methods discussed and others can reduce energy use. Energy conservation is not only possible, but has become an economic necessity for the greenhouse crop industry.

The importance of a thorough investigation before investing in an energy-saving technology cannot be overemphasized. Investments, particularly those

involving a large capital commitment, must be viewed over the life of the asset, rather than just considering the initial cost. The life of the investments and pattern of future cash flows affect the return on investment and net energy savings. Discounted cash flow analysis discounts the value of future cash flows to the present at a specified discount rate, which allows different investments to be compared on an equal basis. An investment unacceptable at a given discount rate may be acceptable at a lesser rate, so the business owner must also consider the desired or target rate of return on investment.

The net present value of an investment is a direct measure of the increase in net worth that an organization will realize by choosing a given investment. Net present value is an effective means of ranking investments, although the final investment decision hinges on all the quantitative and qualitative factors discussed. The internal rate of return is the discount rate at which an investment will have a zero net present value. How close an acceptable investment's internal rate of return is to the discount rate used in the analysis is a direct measure of the range of discount rates in which an investment will remain acceptable. The profitability index indicates how many present value dollars are being returned for

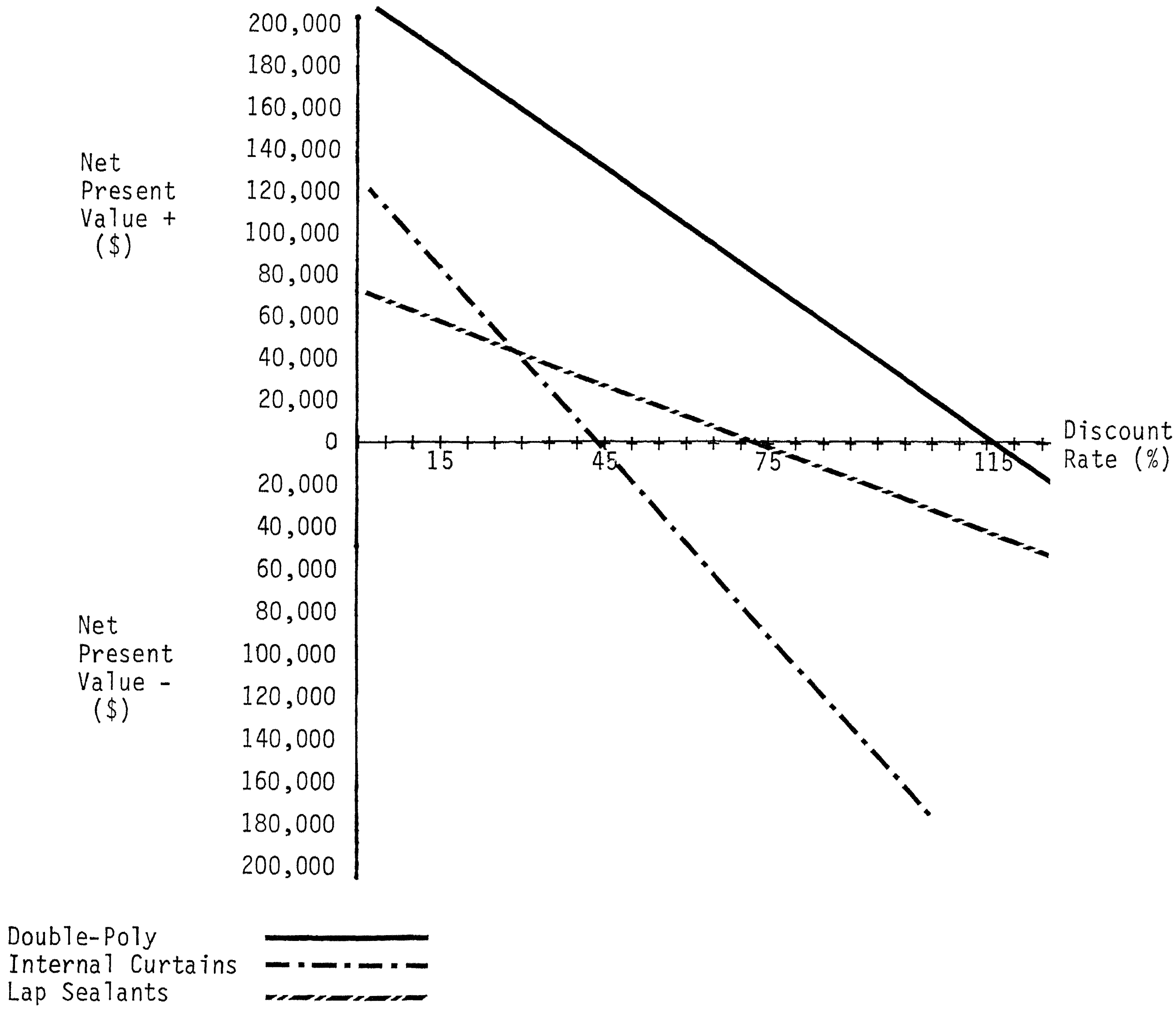

FIG. 4.—Relative position of double-poly, internal curtains, and lap sealants in relation to net present value, discount rate, and internal rate of return for greenhouses heated with #2 oil.

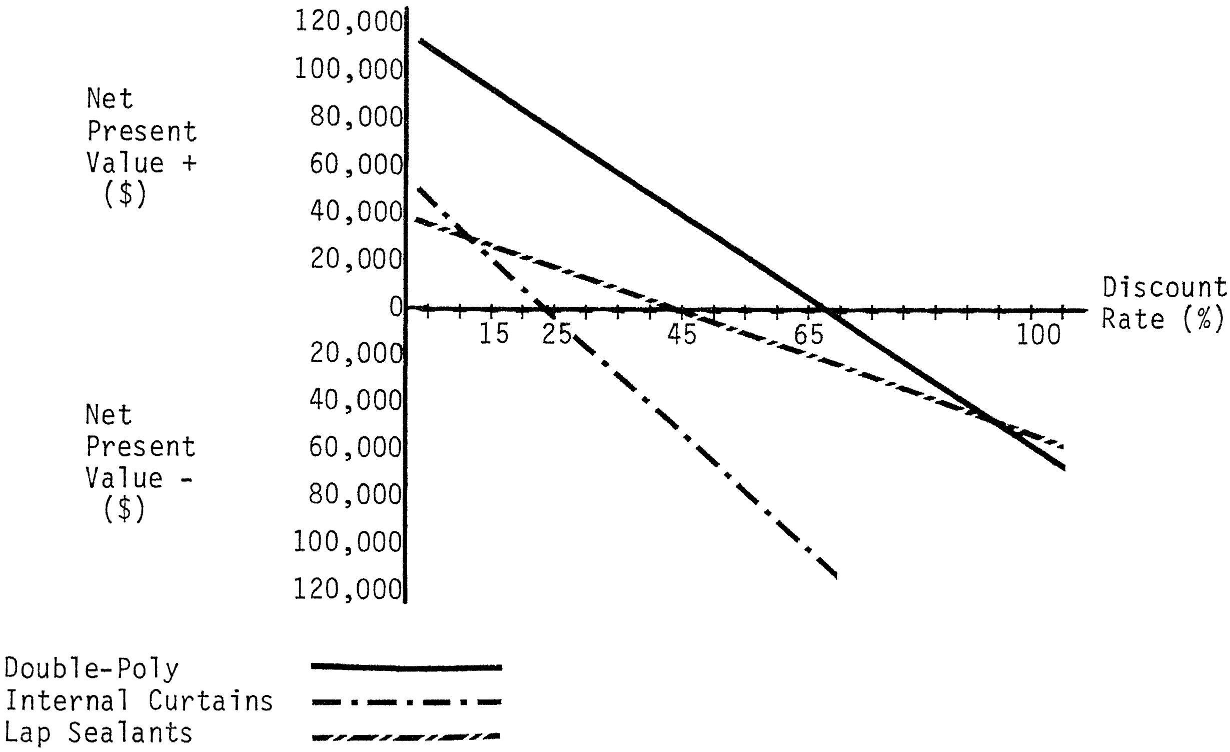

FIG. 5.—Relative position of double-poly, internal curtains, and lap sealants in relation to net present value, discount rate, and internal rate of return for greenhouses heated with natural gas.

each dollar initially invested, which is another measure of the relative profitability of a given investment.

The energy efficiency and relative liquidity and solvency of a given production facility directly influence the investment decision. The capital intensiveness of the various energy conservation investments varies widely, so the effects of an investment on the overall liquidity and solvency of a business are important considerations. Energy conservation matters little if the investment will place the business in a tenuous position to meet other financial obligations. While the average cost of energy accounts for 20% of production costs, obviously the cost of energy for a specific business varies. Thus, the current energy efficiency of a given facility is critical to the investment decision.

Conservation techniques have a different value to growers with varying energy costs. Techniques that have a negative effect on yield and/or quality must be considered carefully. A high percentage of energy savings may be irrelevant if yield decreases. Even minor changes in yield can dramatically influence the relative value of energy conservation.

In making the investment decision, consider the relative stage of development of a given technology. If the technology is relatively undeveloped, equipment obsolescence is more a factor to consider than with a highly refined technology. Increasing productivity may be a better means of fighting high energy costs than making a high capital commitment to a currently available conservation technology.

The decision to invest in a given energy conservation technique must be in line with the return on investment criteria of the individual business. Marginally profitable businesses will have a wider range of acceptable investments than highly profitable businesses that are more exacting in their investment criteria. Growers are not likely to accept a lower return on investment simply in the name of energy conservation.

Investment considerations must take into account the full ramifications of any decision over the life of the asset. Gross reduction in energy use is frequently an overemphasized factor in the investment decision. Net reduction in energy use and net percent energy dollar savings are better measures, but are still incomplete.

Table 11 presents a summary of the valuation

TABLE 11.—Summary of Average Net Energy Dollar Savings, Present Value, Net Present Value, Internal Rate of Return, and Profitability Index for Four Energy Conservation Investments.

Energy Conservation Technique	Average Percent Net Energy Dollar Savings	PV of Total Net Savings ($) per Acre, @ 15% Discount Rate	NPV of Total Net Savings ($) per Acre, @ 15% Discount Rate	Internal Rate of Return	Profitability Index
#2 Oil					
Double-layer, air-inflated polyethylene over glass	45.6%	$212,829.09	$184,515.09	116.36%	7.52
Double-layer, air-inflated polyethylene over glass and internal curtains	47.5%	$221,562.83	$138,802.83	45.03%	2.68
Internal curtains	29.9%	$139,697.19	$ 85,247.19	43.49%	2.57
Glass lap sealants	15.0%	$ 70,156.90	$ 54,910.90	73.27%	4.60
Natural Gas					
Double-layer, air-inflated polyethylene over glass	42.5%	$116,191.93	$ 87,877.93	66.50%	4.10
Double-layer, air-inflated polyethylene over glass and internal curtains	42.2%	$115,259.90	$ 32,499.90	22.68%	1.39
Glass lap sealants	15.0%	$ 41,166.08	$ 25,920.08	45.01%	2.70
Internal curtains	27.7%	$ 75,915.39	$ 21,465.39	22.84%	1.39

measures determined for each technique and a ranking, from highest to lowest net present value, of the energy conservation investments. All of the investments have positive net present values at a 15% discount rate and are therefore acceptable. Certain investments are more acceptable than others, though. The range of discount rates in which the investments would remain acceptable varies considerably.

An investment in double-poly offers the highest net percent energy dollar savings and requires only a moderate capital investment, so double-poly ranks first among the investments analyzed. A combination of double-poly and internal curtains is not a viable investment because double-poly alone provides a similar return.

Internal curtains offer the second and third highest net present value for greenhouses heated with #2 oil and natural gas, respectively. Major consideration should be given to the comparatively high investment required for internal curtains, though. Lap sealants offer 15% net energy dollar savings and the third and second highest net present value for greenhouses heated with #2 oil and natural gas, respectively. In cases where double-poly may not be desirable because of crop considerations, lap sealants may be the best alternative because of the comparatively low investment and high present value dollar return for each dollar initially invested.

GLOSSARY

Capital Budgeting: The process of generating investment proposals, estimating investment performance, evaluating the investment(s), and selecting investment(s) based on acceptance criteria. Capital budgeting is generally concerned with expenditures on assets whose returns will extend for longer than 1 year. Capital budgeting frequently uses discounted cash flow to facilitate the evaluation and accept/reject process.

Cost of Capital: The cost of capital is the firm's total cost of using funds from various sources. For example, debt and equity capital both have a cost to the firm for their use. The cost of debt is the after-tax cost of interest, since interest is a tax deductible expense. Sources of equity capital, such as retained earnings and common stock, also have a cost associated with their use.

Discount Rate: The minimum percentage is a means of evaluating the financial merits of a given proposed investment by considering both the magnitude of the initial investment and the timing of the projected cash flows over the projected life of the investment. The future cash flows are discounted or reduced in value at a discount rate to reflect the time value of money. Present value, net present value, internal rate of return, and profitability index are discounted cash flow valuation methods.

Discount Rate: The minimum percentage rate of return on investment that the investor perceives as being an acceptable rate of return for the investment, given the relative degree of risk involved, etc. Frequently, the rate used is the firm's cost of capital, so that proposed investments can be evaluated as to whether they return at least the firm's cost of capital. Discount rates can be adjusted to reflect a risk premium.

Internal Rate of Return: The internal rate of return is the discount rate at which a given investment will have a zero net present value because the discounted future cash flows are equal to the initial cost of the investment. The relative range of the internal rate of return above the discount rate used in evaluating a given investment is an indication of the desirability of the investment over a range of discount rates.

Liquid (Liquidity): A firm is said to be liquid if it has sufficient current assets (cash, short-term securities, etc.) to meet financial obligations as they become due. Thus, the firm's relative state of liquidity or illiquidity is an indication of that firm's ability to meet financial obligatons and, therefore, the relative financial health of the firm.

Net Present Value: Net present value is the difference between the present value of an investment and the initial cost of the investment. Net present value is a direct measure of the increase in net worth that a firm will realize by choosing a given investment.

Net Worth: The dollar amount invested in the business by the owner(s). In small businesses, net worth is usually the owner's original and subsequent investments in the business plus any retained earnings. In public corporations, net worth includes the value of common stock. Net worth is also called owner's equity.

Opportunity Cost: The opportunity cost of an investment is the potential return on investment for the next best alternative investment.

Planning Horizon: Planning horizon is the time period over which investment proposals are forecast and evaluated. A 10-year planning horizon has been used in evaluating the various energy conservation investments. Planning period is the same as planning horizon.

Present Value: Present value is the value today of the sum of future cash flows generated by a given investment that have been discounted at a given discount rate.

Profitability Index: The profitability index is the present value of the future cash flows divided by the initial investment. The index is a measure of the number of discounted future dollars that a project returns for each dollar initially invested. The higher the index, the more attractive the investment.

Risk Premium: The additional percentage return required for the perceived risk of an investment. For example, United States treasury bills pay a comparatively low rate of interest and are considered to be risk-free. Comparatively, speculative corporate bonds pay a high interest rate due to the additional risk.

Time Value of Money: The financial concept that a dollar today is worth more than a dollar received at some time in the future or, conversely, a dollar to be received at some time in the future is worth less than a dollar today. Dollars that may be received in the future as the result of an investment today are discounted in value to reflect the risk, uncertainty, cost of capital, etc. associated with the given investment. Discounting the future cash flows enables one to compare all dollars as if they are being expended or received today.

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The Ohio Agricultural Experiment Station, as the Center was called for 83 years, was established at The Ohio State University, Columbus, in 1882. Ten years later, the Station was moved to its present location in Wayne County. In 1965, the Ohio General Assembly passed legislation changing the name to Ohio Agricultural Research and Development Center—a name which more accurately reflects the nature and scope of the Center's research program today.

Research at OARDC deals with the improvement of all agricultural production and marketing practices. It is concerned with the development of an agricultural product from germination of a seed or development of an embryo through to the consumer's dinner table. It is directed at improved human nutrition, family and child development, home management, and all other aspects of family life. It is geared to enhancing and preserving the quality of our environment.

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Center Headquarters, Wooster, Wayne County: 1953 acres

Eastern Ohio Resource Development Center, Caldwell, Noble County: 2053 acres

Jackson Branch, Jackson, Jackson County: 502 acres

Mahoning County Farm, Canfield: 275 acres

Muck Crops Branch, Willard, Huron County: 15 acres

North Appalachian Experimental Watershed, Coshocton, Coshocton County: 1047 acres (Cooperative with Science and Education Administration/Agricultural Research, U. S. Dept. of Agriculture)

Northwestern Branch, Hoytville, Wood County: 247 acres

Pomerene Forest Laboratory, Coshocton County: 227 acres

Southern Branch, Ripley, Brown County: 275 acres

Vegetable Crops Branch, Fremont, Sandusky County: 105 acres

Western Branch, South Charleston, Clark County: 428 acres